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Semi-Annual Progress Report for  
THE JOINT NASA/GODDARD-UNIVERSITY OF MARYLAND  
RESEARCH PROGRAM IN CHARGED PARTICLE AND HIGH  
ENERGY PHOTON DETECTOR TECHNOLOGY

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## INTRODUCTION

For more than a decade, individual research groups at Goddard Space Flight Center and the University of Maryland have participated in experiments and observations which have led to the emergence of new disciplines. Having recognized at an early stage the critical importance of maintaining detector capabilities which utilize "state of the art" techniques, the two institutions formulated a joint program directed towards this end. This program has involved coordination of a broad range of efforts and activities including joint experiments, collaboration in theoretical studies, instrument design, calibrations, and data analysis. As part of the effort to provide a stimulating research environment, a series of joint seminars on topics in Astrophysics and Space Physics has been instituted and is held regularly at the University. Many phases of the cooperative effort directly involve faculty, research associates and graduate students in the interpretation of data which is carried out at the Goddard Space Flight Center as well as on campus. Two aspects of this joint program are particularly important. The first is the close tie between scientists at Goddard and the faculty and graduate students at Maryland. This has resulted, for example, in Ph.D. thesis research for a number of graduate students and has been a vital part of the program. The second aspect has to do with the development of advanced instrumentation for space experiments and the cooperative analysis of data from such experiments.

Detailed information on the research projects is available in the annual proposals submitted for this grant. The following are summaries of progress made under this contract. A representative bibliography is also included.

## SOLAR WIND AND INTERPLANETARY STUDIES

Using our sensor on ISEE-3 we have recently reported the first measurements of Fe charge states in two coronal hole-associated high speed streams. Our measurements show that the solar wind emitted from coronal hole regions is characterized by lower charge states than is the solar wind emitted from the quiet corona. We have also been able to determine the charge states of Fe in a driver plasma which originated near a solar flare site and have found that this solar wind flow is characterized by much higher than normal charge states, implying that the solar flare effectively heated the solar atmosphere out to distances of several solar radii. We have also been able to measure solar wind Fe and Si-S charge states in the postshock "sheath region" preceding the driver plasma.

Using the plasma composition experiment (CHEM) on the AMPTE CCE spacecraft we have extended solar wind composition measurements up to and including iron. Results obtained add support to the idea that solar energetic particles are accelerated out of coronal material.

Several upstream particle events were observed on several occasions when an unusually dense solar wind compressed the earth's magnetosphere allowing the AMPTE/CCE spacecraft to sample the magnetosheath and upstream region. Results obtained for various intensity ratios indicate that there is little, if any, magnetospheric contribution to the observed upstream particle population.

## MAGNETOSPHERIC STUDIES

Eight event intervals from the January-June 1983 timeframe have been chosen by the Coordinated Data Analysis Workshop (CDAW) 8 for the study of magnetotail dynamics and its relationship to substorm activity and the

possible formation of plasmoids. Our study using the ULECA sensor on ISEE-3 enabled us to present typical energy spectra and relative abundance ratios for suprathermal  $H^+$  and  $H^{+2}$  ions during these event time periods.

Using the CHEM spectrometer on the AMPTE/CCE spacecraft we have been able to report on the radial distribution of  $He^+$  and  $He^{++}$  ions during both quiet and active magnetospheric conditions. The radial profiles vary with energy largely reflecting the energy dependence of the charge exchange cross sections. During storm times both species penetrate more deeply into the magnetosphere, consistent with convective flows at these energies. Other ions have also been studied and it has been determined that charge exchange processes altered the relative abundance of some species so that the observed ring current ions do not directly reflect the abundances of initially injected ions.

#### ACCELERATION AND PROPAGATION OF SOLAR ENERGETIC PARTICLES

It has been found that for ion events whose time-intensity profiles are characterized by very fast rise and decay times the major ion species H, He, O, and Fe all exhibit scatter-free behavior with differences that appear to be organized by particle energy and charge-to-mass ratio. Using a more realistic model including focused transport to study these events it has now been found that for sufficiently large interplanetary scattering mean free paths, fits can be obtained with pulses of width comparable to our observations, and with wakes whose decay is rapid enough to be consistent with our observations.

During the reporting period, Dr. Chee Ng of the Department of Mathematics, University of Malaya, visited the University of Maryland, working on the derivation of a new equation for the transport of energetic particles in an evolving interplanetary flux tube, carried by a spatial and time

dependent solar wind. This allows one to study the effect of various solar wind disturbances on interplanetary particle transport.

#### FUTURE AREAS OF DEVELOPMENT

The Maryland experiments on several spacecraft have used improvements and refinements to the basic ion composition and charge states measurement method using a combination of electrostatic deflection in high voltage regions and total energy measurements with solid state detectors. Recently, new techniques have allowed the complete and simultaneous determination of all of the important ion parameters. Newer instrumentation to achieve comprehensive measurements of ionization state, mass, energy and arrival direction, combining electrostatic deflection and total energy measurement with a time-of-flight measurement has proven successful on the AMPTE/CCE CHEM experiment. The SWICS sensor for the ESA ULYSSES spacecraft is expected to be launched in 1990 and should result in significant advances in solar wind compositional and charge state studies.

Techniques are now being explored for the measurement of secondary electrons which are characteristically emitted when ions hit a target material. Development efforts in this area include the investigation of ultra-thin foils for very low energy threshold measurements, and the systematic study of electrostatic focusing techniques to achieve good efficiencies in the acceleration and focusing of secondary electrons towards curved microchannel plates that have been found to be excellent detectors of secondary electrons.

The development of a position-sensing microchannel plate assembly of large area to increase the resolution of sensors similar to SWICS, or to have a greatly increased collecting power while maintaining a high resolution, is

continuing.

Practical, low cost, low power consumption data processing units which have the effect of "compressing" data during relatively sophisticated on-board data processing, before it is transmitted to the ground, are being developed for future missions.

#### DETECTOR AND SENSOR RESPONSE STUDIES

The University of Maryland is attempting to refurbish an accelerator facility for use in our laboratory. For many years we have studied the characteristics of the Time-of-Flight vs. Energy telescope using heavy ion beams accelerated by the GSFC and MPAe Van de Graaf accelerators. These studies are continuing but the availability of a multiple-species ion source in our laboratory would greatly facilitate the development of our future time-of-flight sensors.

#### HIGH ENERGY COSMIC RAYS

The Low Energy Antiproton Experiment (LEAP) is a balloon-borne measurement of the cosmic ray antiproton flux over the 0.2-2 GeV energy range near the top of the atmosphere. This flux is of great interest to particle and cosmic ray physicists as well as to astronomers because it is much larger than expected on the basis of standard theory, and might therefore, be evidence for hitherto unseen massive elementary particles whose existence is hinted at in other astrophysical observations.

The apparatus is now in the final stages of assembly and at the beginning of July will be shipped to Prince Albert (near Saskatoon, Saskatchewan), in Canada for final flight preparations and to await favorable flight conditions. The experiment must be flown from a northern location where the

flux of low energy antiprotons is large.

#### SOLAR ENERGETIC PARTICLE STUDIES

Efforts are continuing to understand kilometer wavelength shock associated radio events. These radio bursts are well associated with interplanetary proton events and potentially provide a more direct link between shocks in the low corona and proton acceleration. While it is difficult to provide criteria to uniquely separate these bursts from other fast drift events, evidence has been provided for their existence and for the association with interplanetary protons.

A study to understand modes of particle acceleration in which gamma-ray fluxes and interplanetary proton fluxes were compared has been interpreted in terms of two distinct modes of particle acceleration to establish a correlation between these fluxes.

A study of interplanetary shocks over an extended period including the last two solar maxima has been undertaken. Part of this is directed at understanding the evolution of the shocks and to investigate their large scale structure in order to be able to predict their potential for efficiently accelerating high energy particles.

#### X-RAY ASTRONOMY

An all-sky survey of fast x-ray transients of duration  $5\text{s}-10^4\text{s}$  has been completed. Several events were uncovered that were not identified with known rapidly varying sources. Preliminary data analysis of these events has been completed, work is progressing on modeling and interpreting the results, incorporating additional results from previous x-ray observations.

Work using nonlinear techniques to analyze x-ray timing data has

continued. Calibration of the prototype detector for the Broad Band X-ray Telescope has also continued. The x-ray lines and bremsstrahlung continuum produced have further enabled the analysis of continuum data from a thin mylar target.

The analysis and interpretation of x-ray observations of stellar systems with the HEAO-2 and EXOSAT satellites continues. Preliminary results have been presented and additional analysis supports a model for the soft x-ray pulsations which introduces a new phenomenon, the presence of x-ray dark magnetic poles on the surface of the white dwarf.

X-ray spectral analysis continues on the EXOSAT observation of the dMe visual double star Gliese 867AB.

Other studies on such topics as x-ray emission from clusters of galaxies and consequent constraints on dark matter, the nature of the continuum in active galaxies and the inferences that one can obtain from a study of the emission line spectra of these objects, and a quantitative assessment of the spectral contributions of major classes of extragalactic sources to the overall cosmic x-ray background, continue.

#### LOW ENERGY GAMMA-RAY ASTRONOMY

Research using high resolution gamma-ray spectroscopy of celestial sources in the 20 keV to 20 MeV energy range to search for and study narrow lines in the low-energy gamma-ray spectrum continues. Although a young field, conclusive results are already in demonstrating the potency of applying nuclear spectroscopy to astrophysics for probing high-energy astrophysical processes such as are known to exist in the vicinity of neutron stars and black holes.

The Gamma-Ray Imaging Spectrometer (GRIS) is nearly ready to be carried



above the earth's atmosphere on high altitude balloons. It will measure gamma-ray fluxes that are 5 to 10 times weaker than could be detected by the best previous instruments.

The Transient Gamma-Ray Spectrometer (TGRS) is a satellite-borne instrument to perform high resolution studies of the spectra of gamma-ray bursts. It will make spectral measurements with typically 40 times better energy resolution than the best previous instrument. It is planned for flight on the WIND spacecraft, part of the Global Geospace System (GGS) mission to be launched in the early 1990's.

#### MEDIUM ENERGY GAMMA-RAY ASTRONOMY

A new instrument is being developed to cover the medium energy range and extend the spectral coverage down to 1 MeV in one instrument, with good sensitivity and angular resolution. A balloon flight version of this new instrument is nearly ready and the first objective will be to study Seyfert galaxies.

#### THEORETICAL ASTROPHYSICS

A program in cosmic ray astrophysics placing particular emphasis on the physics and radiation mechanisms in compact sources both on stellar and galactic scales, such as pulsars and active galactic nuclei, is being pursued.

Research in high energy radiation from pulsars, with particular emphasis on processes in superstrong magnetic fields is being conducted, as is the modelling of the emission of similar radiation from active galactic nuclei.

Other research pertaining to cosmology and the interplay between cosmology and particle physics is being performed, as is solar flare research emphasizing gamma-ray line and neutron production in these events. Research

on other topics continues as well.

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